

PATENT SPECIFICATION

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(54) A METHOD OF RECLAIMING WATER AND COAL FROM COAL-TREATMENT UNDERFLOW BY TWO-STAGE SEPARATION OF SOLIDS

(71) We, AMERICAN MINECHEM CORPORATION, a Corporation of the State of Pennsylvania of Coraopolis, Pennsylvania 15108, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to coal processing, and particularly relates to a method of reclaiming water and coal from an aqueous slurry of coal and ash fines.

Mechanized coal preparation plants use large quantities of water to remove coal fines from the coal. The effluent or underflow from the wash treatment typically contains 5 to 15% solids of coal and ash having particle sizes in the range of 150 microns and less (i.e. 100 mesh Tyler sieve). Typically, the underflow is flocculated by addition, of, for example, starch or polyacrylamide in a thickener. The solids content of the underflow is increased to typically about 50% in the thickener, and water reclaimed for recirculation to the coal washing plant.

The thickened underflow is then generally pumped to a settling pond where the solids settle out and the claimed water is made available for reuse in the coal washer. Such settling ponds are, however, increasingly difficult to construct and maintain. There is often limited land available at the coal washing plant, which requires pumping of the underflow over long distances at substantial cost. Moreover, even where there is land available adjacent the washing plant, environmental laws have made such settling ponds difficult and expensive to construct and operate in compliance with state and federal regulations. And, permanent use of settling ponds presents the problems and

costs of disposing of the sediment. In addition, such settling ponds result in loss of the coal present in the thickened underflow.

Recently, various methods have been proposed for reclaiming the coal from the underflow. One of these processes is the coal beneficiation process described in United States Patent No. 3,665,066. Instead of flocculation in a thickener, a hydrocarbon such as kerosene of light fuel oil is added to the underflow in amounts typically of about 2 to 10% by weight of the solids in the underflow. The mixture is then agitated by conventional apparatus. The carbonaceous particles, being lyophobic to the water and lyophilic to the hydrocarbon, are preferentially wetted by the hydrocarbon and coalesce into dewatered, coarser agglomerates generally of diameters of up to 1 millimeter, while the other solids (which are lyophilic to water) remain suspended in the water. The carbonaceous agglomerates, in turn, are separated from the water and ash in a conventional separator, e.g. elutriator, cyclone or spiral, and the separated agglomerates pelletized in a balling device using seed particles of coarser coal. The difficulty with this process is that the water still contains roughly 1 to 5% solids, and, therefore, cannot be utilized in the coal washing plant. Generally, the effluent is still discharged to a settling pond. There, the solids are settled out to enable the water to be reused or, alternatively, discharged into rivers and streams in compliance with state and federal environmental regulations.

The present invention overcomes these difficulties and disadvantages of previous water reclaiming techniques. It totally eliminates the need for a settling pond, while reclaiming the water for use in a coal washing plant. Furthermore, it provides a method for reclaiming the coal fines from

existing settling ponds, while optimizing the reclaim process and eliminating the environmental and safety hazards of the numerous existing settling ponds.

5 The invention provides a method of reclaiming water and coal from an aqueous slurry of coal and ash fines; comprising forming a first mixture by adding to the said
10 slurry a liquid which is lyophobic to water and ash and which is lyophilic to coal; agitating the said first mixture to agglomerate the coal fines therein; separating the agglomerated coal fines from the said first mixture whereby a
15 substantially non-coal slurry is formed; adding a flocculant thereto which is lyophobic to water and which is lyophilic to ash to form a second mixture; and precipitating flocculated solids from the
20 said second mixture whereby water is separated from the said second mixture to form flocculated tailings, and separating flocculated solids from the said flocculated tailings whereby a substantially solids-free
25 aqueous solution of flocculant is formed.

Said lyophobic flocculant is preferably of a molecular weight greater than 100,000, preferably greater than 1,000,000, and most desirably between 3,000,000 and
30 15,000,000. The separated flocculated solids preferably are dewatered and pelletized as hereinafter described.

Preferably, the method provides a closed system for a coal washing plant so that only
35 relatively small quantities of additional fresh water are needed for continuous operation of the coal washing plant. This preferred embodiment is performed by recirculating the water separated from the
40 non-coal aqueous slurry to the coal washing plant, and preferably also recirculating the solids-free aqueous solution to the second mixture or the coal washing plant. Where the solids-free aqueous solution contains
45 substantial quantities of flocculant, the flocculant is preferably reused in the precipitation step; and the water of the solids-free aqueous solution is clarified during precipitation, separated from the
50 second mixture, and recirculated to the coal washing plant.

Another preferred embodiment involves optimizing the operating efficiency of the method, while reclaiming the coal from
55 existing settling ponds. Specifically, while the method is utilizable with slurries of widely varying solids concentration, generally 5 to 40% solids content and typically 20 to 25% solids content by
60 weight in the slurry is provided for efficient operation. Typically, the aqueous slurry as it comes from a coal washing plant is of relatively low solids content, e.g. 5 to 15%.
65 An aqueous slurry of coal and ash fines having relatively high solids content, i.e. at

least 50% solids by weight, is available from the sediment of existing settling ponds. By mixing the high solids aqueous slurry with the low solids aqueous slurry in the appropriate proportion, the operation of
70 the method can be optimized and the refuse of existing settling ponds can be removed and the coal fines reclaimed.

The coal separated from the first mixture may be in certain instances utilized directly
75 in that form. However, the agglomerated coal fines are preferably pelletized into larger and dense coal particles suitable for universal use. The pelletizing may be accomplished by the balling procedure described in United States Patent No. 3,665,066, cited above. Preferably,
80 however, the pelletizing is accomplished by adding to the separated agglomerated coal fines a binder, such as a heavy hydrocarbon, that is lyophobic to water and lyophilic to coal to form a third mixture and agitating the third mixture to dewater and
85 pelletize the agglomerated coal fines.

Other details, objects and advantages of the invention will become apparent as the following description of the presently preferred embodiments and presently preferred methods of practicing the same
90 proceeds.

In the accompanying drawings are shown presently preferred embodiments of the invention and are illustrated present preferred methods of practicing the same,
95 in which:

Figure 1 is a schematic of a method of reclaiming water and coal from coal treatment underflow by two-stage separation of solids; and
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Figure 2 is a schematic of a second, alternative method of reclaiming water and coal from coal treatment underflow by two-stage separation of solids.
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Referring specifically to Figure 1, a method is shown for reclaiming water as well as coal from the underflow from a coal washing plant. Aqueous slurry 10 of coal fines and ash fines typically of relatively low solids content, e.g. 5 to 15% solids, flows from a coal washer through a conduit or pipe. "Ash fines" are small particles of essentially non-carbonaceous material present in mined coal, material that generally appears as ash rather than volatiles on burning of the coal. Preferably, aqueous slurry 10 is mixed with aqueous
110 slurry 11 of coal and non-coal preferably of relatively high solids content, i.e. at least about 50% solids, from the sediment of an existing settling pond adjacent the coal washing plant. The mixture of slurries 10 and 11 form a processable aqueous slurry 12 containing preferably between about 5 to 50%, and most typically 20 to 25% solids content by weight of coal and ash fines.
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Added to aqueous slurry 12 at the inlet to agitator apparatus 13 is a liquid 14 that is lyophobic to water and ash fines and lyophilic to coal fines to form a first mixture.

"Lyophilic" as used herein means that, in a disperse system, there is a marked affinity (wettability) between a disperse component and the dispersion medium and/or another disperse component. Some examples are glue and water, rubber and benzene. "Lyophobic" as used herein means that, in a disperse system, there is substantially non affinity (wettability) between a disperse component and the dispersion medium and/or another disperse component. Examples are colloidal "solutions" of metals.

Compositions particularly suitable for lyophobic liquid 14 are hydrocarbons such as fuel oil and kerosene. Also suited are creosote, filtered anthracene oil, hydrogenated filtered anthracene oil, lubricating oil such as SAE-20, and chlorinated biphenyls. Heavier hydrocarbon liquids such as heavy crude petroleum and coal tar may be utilized in certain instances, but these heavier hydrocarbons are not preferred. Heavy hydrocarbon liquids also typically contain groups lyophilic to ash fines as well as carbonaceous fines and, therefore, do not provide the degree of separation of coal fines from ash fines preferred in the present method.

Lyophobic liquid 14 is added in measured amounts to control the agglomeration of the coal fines as hereinafter described. Preferably, liquid 14 is added in amounts of from 2 to 10% by weight and preferably from 3 to 7% by weight of the total solids in aqueous slurry 12 for high recovery, e.g. 88-98% recovery. Lesser amounts of as little as 1% by weight and greater amounts up to and exceeding 30% by weight may in some instances be utilized, however, such lesser and greater amounts are not preferred because sufficient agglomeration and binding of the coal fines is not provided, on the one hand, and a waste of highly refined petroleum or coal tar results, on the other hand.

The first mixture of aqueous slurry 12 and lyophobic liquid 14 is agitated in agitator apparatus 13. Apparatus 13 may be of any suitable agitating device such as a modified turbine, disc or cone impeller mixer. Preferably, however, agitator apparatus 13 is a tank equipped with a motor driven propeller 13A extending to the bottom portion of the tank, such as a Premier Mill.

During the agitation in agitator apparatus 13, the coal fines are preferentially wetted by lyophobic liquid 14, which is preferably immiscible to the water, and the coal fines agglomerated into coarser particulates. The

size of the agglomerates is dependent primarily upon the percentage of lyophobic liquid 14 added to the aqueous slurry 12; for the preferred percentages of 2 to 10% by weight, the agglomerates typically have sizes from about 1 to 2 millimeters. The time required to effect agglomeration is generally dependent upon the degree of turbulence or agitation, with the shorter agglomeration time being associated with the high agitation speed. During the agitation, the mixture changes from a black color associated with aqueous slurry of coal to a lighter color associated with an aqueous slurry of ash. The color change occurs in roughly half the time required for effective agglomeration of the carbonaceous particles. The coal agglomerates, being impregnated with lyophobic liquid 14 which is generally less dense than water, will tend to float to the top in the first mixture.

The agglomerated first mixture 15 is then pumped to a separator 16 which separates the coal agglomerates from the water and ash fines by size and/or density. Preferably, separator 16 is a sieve bend of an appropriate mesh size, e.g. 100 or 200 mesh Tyler, such as that manufactured by authority from DSM NV Vedernaldse Staatsmijnen. Alternatively, other commercially available size separators such as an elutriator, cyclone or spiral separator may be utilized. Alternatively, the agglomerates may also be separated in a float-sink tank where the coal agglomerates, which tend to float, are skimmed off by a rotating paddle through an overflow, while the water and unagglomerated ash fines, which tend to sink, are removed through the bottom of the tank as a non-coal slurry underflow 24 substantially free of coal fines and lyophobic liquid.

The separated agglomerates 17 of coal fines may then be processed through dewatering apparatus 18, such as a centrifuge, to remove water adsorbed on the agglomerates. As a matter of convenience, separated water 19 is recirculated back to and admixed with lyophobic liquid 14. Dewatering apparatus 18 is not, however, necessary where the agglomerates are dried and used in that form, and is not generally necessary or preferred where the agglomerates are pelletized as hereinafter described.

Coal agglomerates 17 or 20 may be utilized in that form. Preferably, however, coal agglomerates 17 or 20 are pelletized generally to particle sizes of 0.05 to 0.75 inch in diameter for more universal use. The pelletizing is preferably accomplished by feeding coal agglomerates 20 to a pelletizer 21 such as the 39-inch pelletizing disc manufactured by Dravo. Binder liquid

22 is mixed with coal agglomerates 20 by premixing or direct feeding to the pelletizing disc or tumbler. Binder liquids particularly suited for this purpose are heavy hydrocarbons, such as coke-oven coal tar, oil-shale crude, petroleum crude or heavy fuel such as Bunker C, which is preferably heated to, for example, 100°C. to increase fluidity. The requirement for the binder liquid is that it be capable of producing a coherent pelletized product 23 in which the coal agglomerates are bonded together with sufficient strength to permit mechanized processing and handling of them without substantially crumbling. In this connection, it may be desirable that the pelletized product 23 be subsequently oven dried at, e.g. 100°C., to bond the binder to and within the agglomerates. An accelerator is also preferably included in binder liquid 22 to hasten bonding of the binder in shorter times and/or at lower temperatures.

The size of the pelletized coal product 23 is controlled primarily by the percentage of binder 22 utilized, and the speed of rotation of the pelletizing disc or tumbler and residence time of the particulate within the pelletizer. Typically, binder liquid 22 is added in amounts from 5 to 25% by weight of coal agglomerate 20, with the least amount consistent with good pelletizing being most desirable. Typically, the residence time within the pelletizer 21 is about 10 minutes at a rotation speed of between roughly 10 and 20 rpm. The size and density of the pellets may also be controlled by addition of nuclei such as described in United States Patent No. 3,665,066, above referenced. However, seeding is not preferred because the coal nuclei generally have a higher ash content than the coal agglomerates and, therefore, reduce the carbonaceous content of the resulting pelletized product 23. A pelletized product of controlled size is generally obtainable by the pelletizing operation as described within the range of 0.05 to 0.75 inch in diameter.

Meanwhile, non-coal slurry 24 from separator apparatus 16 is circulated through suitable piping or conduit to thickener 25. The underflow 24 is an aqueous slurry substantially free of coal fines and lyophobic liquid 14, but still containing approximately 10% solids by weight mostly of ash fines.

At the inlet to the thickener 25, non-coal slurry 24 is mixed with a flocculant solution 26 of flocculant lyophobic to water and lyophilic to ash to form a second mixture. Suitable flocculants for this purpose are high molecular weight polyacrylamides $(CH_2CH CONH_2)_n$, polyethylene oxides $(OCH_2CH_2)_n$, polyethylene imines $(CH_2CH_2 NH)_n$, polyvinyl pyrrolidones $(C_4H_5NO)_n$, polysaccharides $(C_6H_{10}O_5)_n$, and copolymers and mixtures of these polymers with varying side and end groups, of greater than 100,000 molecular weight. Such high molecular weight polymers are preferably greater than 1,000,000 molecular weight, and most desirably between 3,000,000 and 15,000,000 molecular weight, with 9,000,000 molecular weight considered optimum. Higher molecular weight polymers of up to and greater than 20,000,000 may be used; however, such overly high molecular weights are not preferred because they are unduly expensive to make and do not provide residence times during flocculation that result in high clarity in the reclaimed water. Flocculants available commercially which may be utilized to prepare flocculant solution 26 are set forth in Table I below.

TABLE I

	Manufacturer	Trade Mark of Flocculant
90	Allied Colloids (Y.C.L. Grade)	Polyflok 91APA
	Allied Colloids (Y.C.L. Grade)	Polyflok 93APA
	Allied Colloids (Y.C.L. Grade)	Polyflok 95APA
	Allied Colloids (Y.C.L. Grade)	Polyflok 63 AP/W
	Allied Colloids (Y.C.L. Grade)	Polyflok 13CL
95	Allied Colloids	Filtaflok 25AP
	Allied Colloids	Magnafloc R155
	Allied Colloids	Magnafloc R156
	Allied Colloids	Magnafloc R270
	Allied Colloids	Magnafloc R140
100	Allied Colloids	Magnafloc LT22
	Allied Colloids	Magnafloc LT24
	Allied Colloids	Magnafloc LT25
	Allied Colloids	Magnafloc LT26
	Badische-Anilin-& Soda Fabrik, AG	Sedipur TF
105	Badische-Anilin-& Soda Fabrik, AG	Sedipur LK4011
	Badische-Anilin-& Soda Fabrik, AG	Sedipur LK4034

TABLE I (cont.)

	Manufacturer	Trade Mark of Flocculant	
5	Stockhausen	Praestol 444K	
	Stockhausen	Praestol 114	
	Stockhausen	Praestol 115	
	Stockhausen	Praestol 2850	
	Hercules Powder	Hercofloc 810	
	Hercules Powder	Hercofloc 813	
10	Hercules Powder	Hercofloc 817	
	Nalco	Nalfloc N603	
	Nalco	Nalfloc N610	
	Nalco	Nalfloc N671	
	Nalco	Nalfloc N672	
15	Nalco	Nalfloc N673	
	Nalco	Nalfloc A373	
	Nalco	Nalfloc A375	
	Nalco	Nalfloc A378	
20	American Cyanamid	Superfloc 500 Series	
	American Cyanamid	Superfloc 800 Series	
	American Cyanamid	Superfloc 992	
	American Cyanamid	Superfloc 521	
	Dow Chemical	Purifloc C31	
	Dow Chemical	Purifloc C32	
25	Dow Chemical	Separan AP273	
	B.T.I.	C.110	
	B.T.I.	A.110	
	B.T.I.	A.130	
	B.T.I.	A.150	
30	B.T.I.	A.100(PWG)	
	B.T.I.	A.110(PWG)	
	B.T.I.	A.130(PWG)	
	B.T.I.	A.150(PWG)	
	B.T.I.	N.100(PWG)	
35	Such lyophobic flocculants are mostly anionic; however, cationic flocculants are available and are preferred as an alternative or a complement to anionic flocculants in certain applications. Specifically, anionic flocculants are generally not effective to flocculate very small size fine particles, which generally carry a negative surface charge, while the cationic or positively charged flocculants are able to neutralize the surface charge of such small particles and produce faster settlement rates and reclaim water of higher clarity. However, cationic flocculants generally tend to be more expensive because the materials needed to make the polymer cationic are generally higher in price. In addition, cationic flocculants tend not to be as efficient in flocculation of large particle fines because cationic flocculants generally are of lower molecular weight than anionic flocculants. Cationic flocculants also tend to be more difficult to dissolve and, therefore, reduce the speed and ease with which the flocculant solution may be prepared. In addition, non-ionic flocculants of high molecular weight may be used in certain applications where the composition and nature of the ash fines permit.		
40	Lyophobic flocculant 26 is preferably prepared in dilute solution by known procedures. The object of the preparation is to disperse the lyophobic flocculant, which is in dry power form, in water without producing agglomerates of the powder and without degradation of the high molecular weight polymers, which are sensitive to the shear forces. Manual mixing is generally not preferred because of the time and care necessary to avoid the formation of gelatinous lumps or agglomerates, which are ineffective and wasteful. Preferably, the flocculant solution is automatically prepared batch-wise by use of large mixing and stock tanks. The flocculant solution is prepared in the mixing tank utilizing masterbatching dispersion. The preparation is preferably commenced by introducing water to the mixing tank until the impeller is covered. Then, the water and flocculant powder are simultaneously dispersed and introduced to the mixing tank through a disperser unit such as the Bretby Autex disperser, which disperses the flocculant powder into a high velocity, thin water stream. When a measured amount of flocculant powder has been delivered to the mixing tank through the disperser, the		
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5 mixing tank is further filled with water to a level corresponding to the desired dilution of the flocculant in the solution. Stirring with the impeller is thereafter continued until the flocculant powder is sufficiently dissolved in the water. When a signal is received from the stock tank indicating a low level in that tank, the prepared batch is emptied from the mixing tank to the stock tank, and the preparation cycle again commenced in the mixing tank. The dilution of the flocculant in the solution is thereby automatically controlled, and the only attention required is the addition of powdered flocculant to a suitable hopper at the mixing tank.

10 Lyophobic flocculant 26 is then added to substantially non-coal slurry 24 in measured amounts of less than 0.2% by weight and preferably between 0.001 and 0.1% by weight of solids (dry weight) in slurry 24. Thorough mixing of the flocculant solution with the non-coal slurry is essential to efficient precipitation of the flocculated solids, but mixing usually requires application of shear to the polymer molecules from an impeller which ruptures and degrades the polymer. Accordingly, lyophobic flocculant 26 is preferably added to non-coal slurry 24 at the inlet to thickener 25 where high turbulence is produced without the use of an impeller. The turbulent condition provides for better distribution of the flocculant through the slurry and provides maximum surface contact with the fines in the slurry. Thorough mixing of the flocculant can be achieved by adding the flocculant solution at different inlets round the cross-section of non-coal slurry 24 and, if possible, at different points along the length of the pipe through which slurry 24 is conducted to thickener 25. Alternatively, thorough mixing can be provided by spraying the flocculant solution into a cascade of the non-coal slurry, or spraying the flocculant solution into the non-coal slurry at several points as the slurry passes through a baffled launder.

50 The amount of lyophobic flocculant 26 added to the non-coal slurry 24 is controlled (i) by dilution of the powder in solution and (ii) by addition of the solution to the slurry. Flocculant must be added to the slurry at a sufficient rate to produce lyophobic flocs, without causing carry-over and waste that accompanies overdosage; and the addition at proper rate is directly dependent on the concentration of solids in non-coal slurry 24, which concentration typically fluctuates widely during operation. Accordingly, the flocculant is preferably prepared in highly dilute solutions in water (typically 0.05% by weight) and large volumes of flocculant

solution supplied to the slurry (0.4 liters per ton of solids [dry weight] processed) so that the dosing can be controlled and varied with precision corresponding to variation in the concentration solids in slurry 24.

To properly control the flocculant addition, both the flow rate and the solids concentration of slurry 24 must be measured, and the solids feed rate to thickener 25 continually computed. The flow of the slurry is preferably measured automatically and continually by a conventional magnetic flow meter; and the solid concentration of the slurry is preferably measured automatically and continually by a twin vibrating tube density meter which continually measures the specific gravity of the slurry. The specific gravity of the water and solids being presumably constant, the solids concentration in the slurry and in turn the solids flow rate to thickener 25 can be computed. Lyophobic flocculant solution 26 can then be automatically metered into non-coal slurry 24 at a varied rate by utilizing a variable speed pump controlled by an electrical signal proportional to the computed solids flow rate, or by opening and closing a servovalve controlled by an electrical signal proportional to the difference between the measured flow rate of the flocculant solution and the desired flow rate for the computed solids flow rate.

Having achieved distribution of lyophobic flocculant 26 through non-coal slurry 24 to form a second mixture, the second mixture is discharged preferably centrally into, for example, conventional thickener 25 as shown. The flocculated solids precipitate or settle to the bottom of thickener 25, while the flocculated particles, being lyophobic to water, continually exude water. The efficiency and rate of precipitation is primarily dependent on the molecular weight of the flocculant polymer and the percentage of flocculant to solids as above described. Preferably, the mixture is gently stirred by motor driven agitator 25A, e.g. at 1 or 2 revolutions per minute, to release occluded water around and between the flocculated solids, as well as aid the release of water from the lyophobic flocs by increasing the pressure of the flocs on each other. A substantially clear layer of water is thus formed at the top of thickener 25, which is separated from the second mixture through overflow 27. This reclaimed water 28 is then circulated through suitable conduit or pipe to a coal washing plant for reuse. Although it may in some instances be turbid, water 28 is sufficiently clear for reuse as processing water in a coal washing plant, i.e. less than 1% solids.

The lyophobic flocculated solids

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precipitate and settle to the bottom of thickener 25 where they are removed as flocculated solids or tailings 29 containing typically between 35 and 70% solids, with 55 to 65% solids being most typical. Flocculated solids 29 are generally solids containing entrained water which may be disposed of in that form. Tailings 29 may, however, be in slurry form. In any case, the solids content of flocculated solids 29 are directly dependent on the pressure of the solids above and around the flocs as they are removed at the bottom of thickener 25, and is effected to only a minor or secondary extent by other variables. Accordingly, the solids content of flocculated tailings 29 can be maintained substantially constant by providing a servovalve at the outlet from the bottom of thickener 25 controlled by an electrical signal proportional to the pressure in the second mixture in the thickener. The pressure of the second mixture is typically measured by a conventional pressure device positioned through the side of thickener 25.

Generally, the flocculated tailings 29 are a solids mixture of consistent composition. Preferably, the flocculated tailings 29, whether in solid or slurry form, are conveyed to pelletizer 30 where the solids are simultaneously dewatered and pelletized. Pelletizer 30 may be any commercially available pelletizer suitable for the particular application. Preferably, pelletizer 30 is a horizontal tumbler type such as a "Y" pelletizer, as shown, or a cylindrical pelletizer. In the pelletizer the flocculated solids are tumbled into lyophobic pellets which are easily handled, and which readily meet specifications and regulations in constructing waste disposal piles. The pellets and water are removed from the pelletizer over screen 31, where the pellets are separated from the water to form a substantially solids-free aqueous solution 33. The pelletized tails 32 are generally spherical pellets, with moisture contents typically of between 20 and 35% by weight and sizes of between 0.25 and 0.75 inch.

In some instances solids-free aqueous solution 33 is sufficiently clear and free of solids and flocculant that it can and will be recirculated to the coal washing plant as reclaimed water. However, even when the dosage rate of lyophobic flocculant 26 is accurately controlled, the percentage of flocculant carryover to solution 33 can be high. It is desirable for economic reasons, as well as for efficient operation of the coal washing plant, to reuse this water containing flocculant in the thickener. Accordingly, water solution 33 is, in usual operation, at present recirculated and admixed with non-coal slurry 24 and/or

lyophobic flocculant 26; and the water of solution 33 reclaimed as overflow water from the second mixture in thickener 25.

In an alternative embodiment, the flocculation and pelletizing steps can be performed concurrently in a wet-pelletizing separator or "aquapelletizer", such as the one commercially available from Ebara-Infilco Company Limited, Palaceside Building 1-1, 1-chrome, Hilotsubashi, Chiyoda-ku, Tokyo, Japan under the tradename "Dehydram". The "Dehydram" pelletizer is a relatively large horizontal rotary cylinder, e.g. 2.4 meter in diameter and 6.7 meter in length, or 3.4 meter in diameter and 9.0 meter in length, that rotates at approximately one revolution each seven to ten minutes. The interior of a "Dehydram" pelletizer consists of three functional sections known as pelletizing, separating and dewatering sections. In the pelletizing section, the non-coal slurry is flocculated by the addition of lyophobic flocculant as above described and at the same time the flocculated solids are in effect precipitated by the mechanical tumbling action given to the mixture to produce pellets of flocculated solids in a water suspension. The resulting, compacted spherical pellets of flocculated solid are suspended in substantially solids-free aqueous solution. In the separating section, the substantially clear water solution is discharged intermittently through small holes in the cylindrical wall of the rotating drum and can be recirculated to the coal washing plant or to the non-coal aqueous slurry 24 based on the conditions above described. The lyophobic pellets are conveyed to the final dewatering section by an internal spiral conveyor. In the dewatering section, the lyophobic pellets are further dewatered by tumbling prior to discharge as cake-pellets of low water content, e.g. 35% by weight. Accordingly, the "Dehydram" pelletizer is capable of simultaneously performing the process of steps of adding lyophobic flocculant, precipitating flocculated solids and separating flocculated solids in one cylindrical device.

Referring to Figure 2, still another alternative method is shown for reclaiming water and coal from coal treatment underflow. The method is the same as the method described with reference to Figure 1 through the separation and pelletizing of the coal fines and the addition of lyophobic flocculant 26 to non-coal slurry 24 to form the second mixture. The second mixture is, however, discharged to deep cone thickener 25' instead of conventional thickener 25 with agitator 25A. The conical apparatus 25' is a settling

vessel of conical or cylindo-conical shape, e.g. 4 meters in diameter, and considerably less settling area than the conventional thickener. The shape and depth of conical thickener 25' provides greater hydrostatic pressure on the flocculated solids discharged from the bottom of the thickener and in turn the solids content of the flocculated tailings can be increased and the use of subsequent dewatering apparatus eliminated. Agitator 25A' is utilized in cone thickener 25' to slightly stir the flocculated solids, adding to the lyophobic action of the flocs and enabling occluded water to escape from around and between the flocs.

The flocculated solids are preferably discharged from cone thickener 25' directly into liquid drain 34, where free water entrained in the flocculated solids may be drained. Liquid drain 34 is described in United States Patent No. 3,423,313, granted to the same applicant and assignee as the present invention. The drain has a foraminal or perforated conduit section, through the porous wall of which the free water can drain. Preferably the foraminal conduit section is surrounded by a vibratory member which vibrates the solids as they pass through the conduit to aid the escape of the entrained liquid. The substantially solids-free solution 33' mostly of water, is circulated from liquid drain 34 to the coal washer for reuse. Alternatively, solution 33' may as above described be recirculated to non-coal slurry 24 and/or lyophobic flocculant 26 when it contains substantial quantities of flocculant.

As it emerges from mechanical thickener 34, flocculated solids 29' usually is a cake-like solid of sufficient low moisture content, i.e. less than 40% by weight, and constant consistency to be disposable. Although not necessary, flocculate solids 29' may be further dewatered and processed through pelletizer 30' to provide more easily manageable tails 32' and reclaim additional water for the system. Pelletizer 30' may be any conventional pelletizer suitable for the application. Preferably, pelletizer 30' is a horizontal tumbler type as schematically shown in Figure 2. The water from pelletizer 30' is recirculated to the second mixture in thickener 25' (if the water contains substantial flocculant and/or solids) or to a coal washing plant (if the water is substantially free of flocculant and solids).

While the preferred embodiments of the invention have been specifically described, it is distinctly understood that the invention may be otherwise variously embodied and used within the scope of the following claims.

WHAT WE CLAIM IS:—

1. A method of reclaiming water and coal from an aqueous slurry of coal and ash fines; comprising forming a first mixture by adding to the said slurry a liquid which is lyophobic to coal; agitating the said first mixture to agglomerate the coal fines therein; separating the agglomerated coal fines from the said first mixture whereby a substantially non-coal slurry is formed; adding a flocculant thereto which is lyophobic to water and which is lyophilic to ash to form a second mixture; and precipitating flocculated solids from the said second mixture whereby water is separated from the said second mixture to form flocculated tailings, and separating flocculated solids from the said flocculated tailings whereby a substantially solids-free aqueous solution of flocculant is formed.
2. A method according to Claim 1, wherein the flocculant used has a molecular weight of at least 100,000.
3. A method according to Claim 1, wherein the said flocculant has a molecular weight of at least 1,000,000.
4. A method according to Claim 3, wherein the said flocculant has a molecular weight between 3,000,000 and 15,000,000.
5. A method according to any of Claims 1 to 4, wherein the water separated from said second mixture is recycled to a coal washing process.
6. A method according to Claim 5, wherein the said solids-free aqueous solution is recycled to the said coal-washing process.
7. A method according to Claim 5, wherein the said solids-free aqueous solution is recycled to the said second mixture.
8. A method according to any of Claims 1 to 7, wherein there is added to the said separated coal fines a liquid binder which is lyophobic to water and which is lyophilic to coal, to form a third mixture and agitating said third mixture to dewater and pelletize the agglomerated coal fines.
9. A method according to any of Claims 1 to 8, wherein the said flocculated solids are pelletized.
10. A method according to Claim 9, wherein the pelletizing of the said flocculated solids is effected at least partially concurrently with the steps in Claim 1 of precipitating flocculated solids and of separating flocculated solids.
11. A method according to any of Claims 1 to 10, wherein the step in Claim 1 of precipitating flocculated solids is effected at least partially concurrently with the step of separating flocculated solids.
12. A method according to any of Claims 1 to 11, wherein the aqueous slurry of coal

and ash fines to be treated is obtained by adding an aqueous slurry of coal and ash fines having a relatively high solids content to an aqueous slurry of coal and ash fines having a relatively low solids content.

13. A method of operating a coalwashing plant in which water and coal are reclaimed from an aqueous slurry of coal and ash fines to any of Claims 1 to 12.

14. A method of operating a coal-washing

plant, substantially as hereinbefore described, with particular reference to Figure 1 or Figure 2 of the accompanying drawings.

HYDE, HEIDE & O'DONNELL,
47 Victoria Street,
London, SW1H 0ES.
Chartered Patent Agents.
Agents for Applicants.

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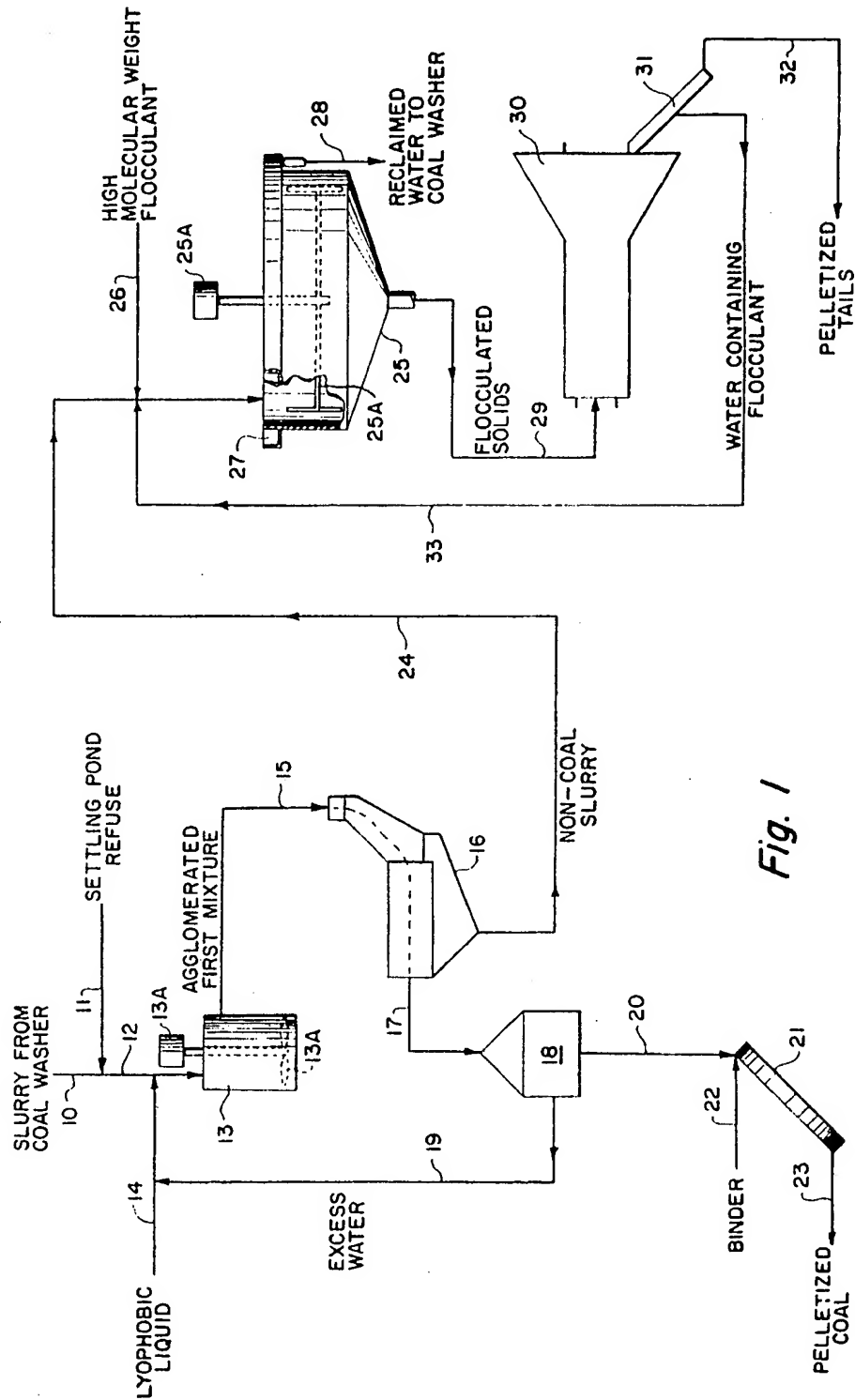


Fig. 1

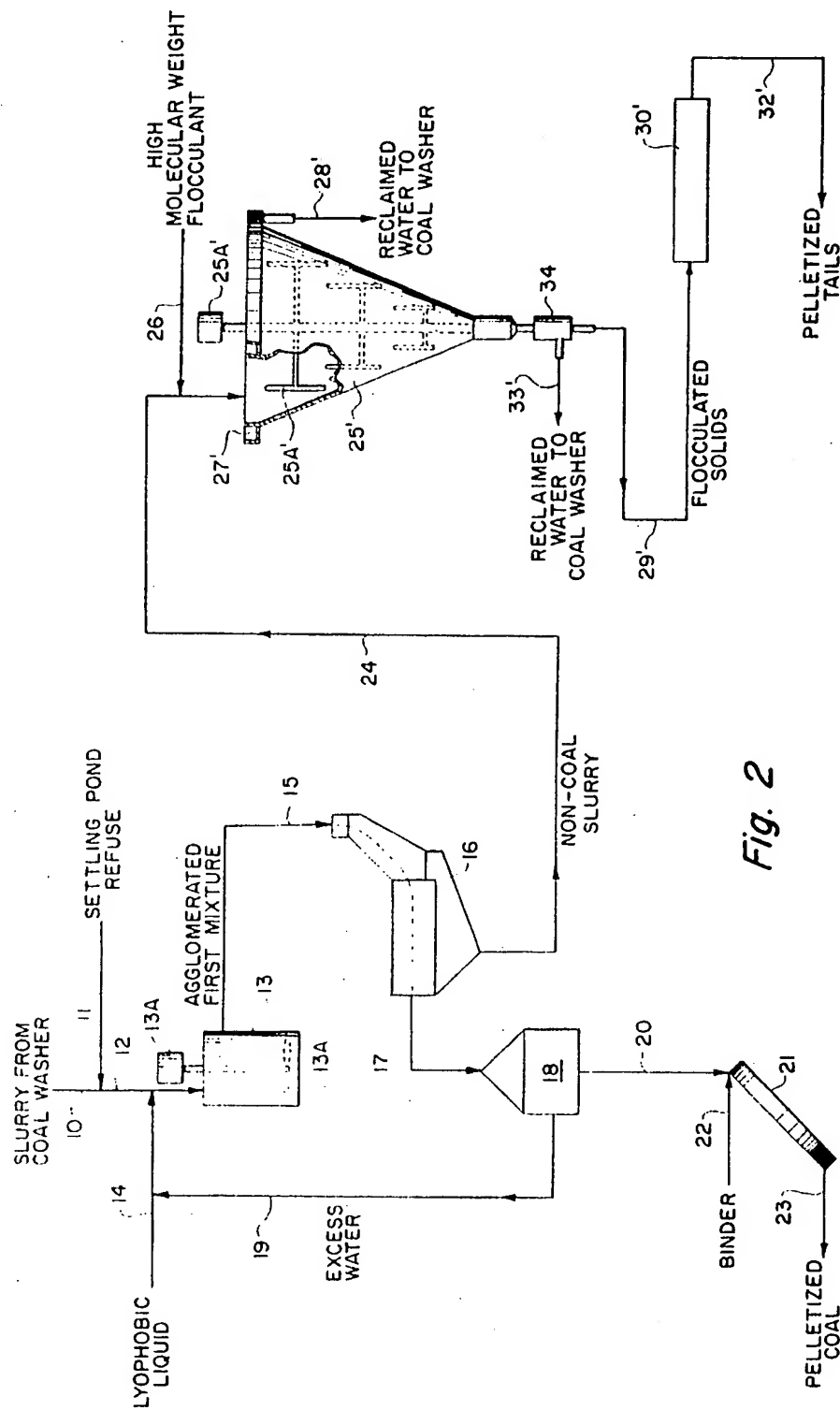


Fig. 2

